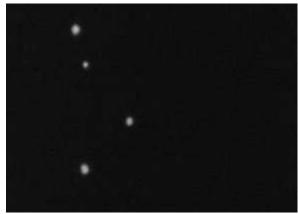# Structure of Flame Balls at Low Lewis-Number

The Structure of Flame Balls at Low Lewis-Number (SOFBALL) experiment explored the behavior of a newly discovered flame phenomena called "flame balls." These spherical, stable, stationary flame structures, observed only in microgravity, provide a unique opportunity to study the interactions of the two most important processes necessary for combustion (chemical reaction and heat and mass transport) in the simplest possible configuration. The previously unobtainable experimental data provided a comparison with models of flame stability and flame propagation limits that are crucial both in assessing fire safety and in designing efficient, clean-burning combustion engines.

The SOFBALL experiment was conceived by Professor Paul Ronney of the University of Southern California and designed and developed by the NASA Lewis Research Center. It was conducted in the Combustion Module-1 (CM-1) of the Microgravity Science Laboratory payload during Space Shuttle Columbia missions STS-83 and STS-94. Mixtures of hydrogen, oxygen, and a third inert component of either nitrogen, carbon dioxide, or sulfur hexafluoride were burned. Video images, radiant fluxes, chamber pressure, temperature, and gas concentrations were measured to characterize flame ball properties and behavior.

Instead of the 15 tests planned, a total of 19 experiment runs were completed on the two missions, and 18 of the mixtures ignited. These mixtures produced from one to nine flame balls, with the mixtures that had more fuel producing multiple flame balls. Most of the tests burned for 500 seconds until the experiment timeout extinguished the flames by turning on a fan. Eleven of the initial burns were ignited by spark a second time, and eight of them burned for an additional 500 seconds until experiment timeout. A total of 60 flame balls were produced.

Flame balls from a mixture of 4 vol % hydrogen in air, 30 sec after ignition. The flame ball diameters ranged from 5 to 15 mm.

From the preliminary data obtained during the test runs, we have made the following conclusions:

1. Steady, nearly stationary flame balls exist in an extended-duration microgravity environment.

2. The extended length of the burns verifies the theoretical predictions that these flames evolve on a very slow time scale, on the order of hundreds of seconds.

3. The flame balls are sensitive to orbiter thrust firings above 50 μg-sec. During free-drift periods, the flame balls were nearly motionless for many minutes, whereas the flame ball moved slightly after vernier thruster firings or water dumps.

4. All the burns, regardless of the inert component of the flame ball, the number of flame balls, or the pressure, produced between 1 and 1.8 W of radiant power, in disagreement with pre-mission predictions.

The SOFBALL experiment accomplished a number of scientific firsts:

- It was the first premixed gas combustion experiment in space.

- It produced the weakest flames ever burned, either on the ground or in space.

- It measured flame ball powers as low as 1 W.

- It produced the longest-lived gas flames ever burned in space.

The SOFBALL experiment also accomplished a number of combustion program firsts:

- Multiple combustion investigations were conducted in a single facility.

- A pressure vessel was breached and recertified on-orbit to handle hazardous gases.

- Spark ignition was used for combustion in space.

- Gases were mixed on-orbit to create new test mixtures.

- Hazardous postcombustion products were cleaned up on-orbit before they were vented into space.

Lewis contact: Dr. Karen J. Weiland, (216) 433-3623, Karen.J.Weiland@grc.nasa.gov
Authors: Dr. Karen J. Weiland and Prof. Paul Ronney
Headquarters program office: OLMSA
Programs/Projects: HEDS, Microgravity Science, STS-83, STS-94, MSL-1, MSL-1R, CM-1

Special recognition: The SOFBALL experiment was mentioned in several publications during and after the STS-94 mission: USA Today and the Associated Press, Science News, and Chemical and Engineering News.